The Relation of the Municipality to the Water Supply

A SYMPOSIUM

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AMSTERDAM, HOLLAND

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History of Establishment of Water Supply to Consumers.—On April 20, 1849, a concession was granted by the municipality of Amsterdam to Mr. C. D. Vaillant for the supply of drinkable water from the dunes, and on June 19, 1851, the royal sanction was obtained for the establishment of the Hill Water Company (principally with English capital), which took over the concession of Mr. Vaillant.

In the years 1852-54 the works of the Hill Water Company were constructed, viz.: An open canal was dug in the dunes at Vogelenzang, near Haarlem, with a length of about two kilometers; a pumping station, three open slow-sand filters and a clear-water reservoir were built in the neighborhood and a twenty-inch cast-iron pipe was laid to Amsterdam via Haarlem, about twenty-two kilometers long. May 1, 1854, the works were opened with eight consumers. On August 17, 1854, the town of Haarlem

granted the concession of its water supply to the same Amsterdam Hill Water Company.

January 1, 1855, the length of the pipe lines was already increased to 41.8 kilometers. In the following year the total delivery of Hill water amounted to about 250,000 cubic meters. In the year 1876, a second cast-iron main pipe, twenty-four inches wide, was laid to Amsterdam and was put in operation in the month of May of the same year. On April 1, 1885, the concession to the Hill Water Company was renewed by the municipality of Amsterdam, wherein the obligation was imposed to build a new water supply from the river "Vecht," at Nigtevecht, near Weesp, for industrial and public use, lawn waterings, municipal establishments, extinguishing of fire, etc.

The Vecht water supply came into operation on May 1, 1888. The works consisted of a pumping station with two settling-basins, four slow-sand filters and a clear-water reservoir at Weespercarspel; an intake at Nigtevecht with a forty-eight-inch cast-iron feeding pipe of a length of nearly 4,500 meters to the above-said pumping station, two head-mains to Amsterdam, of twenty-seven-inch and twenty-four-inch width, each 9,250 meters long, and separate pipe lines in the town. This Vecht water supply, established with the purpose of superseding the Hill water supply, which could no longer deliver its water under a sufficient pressure, did not satisfy expectations.

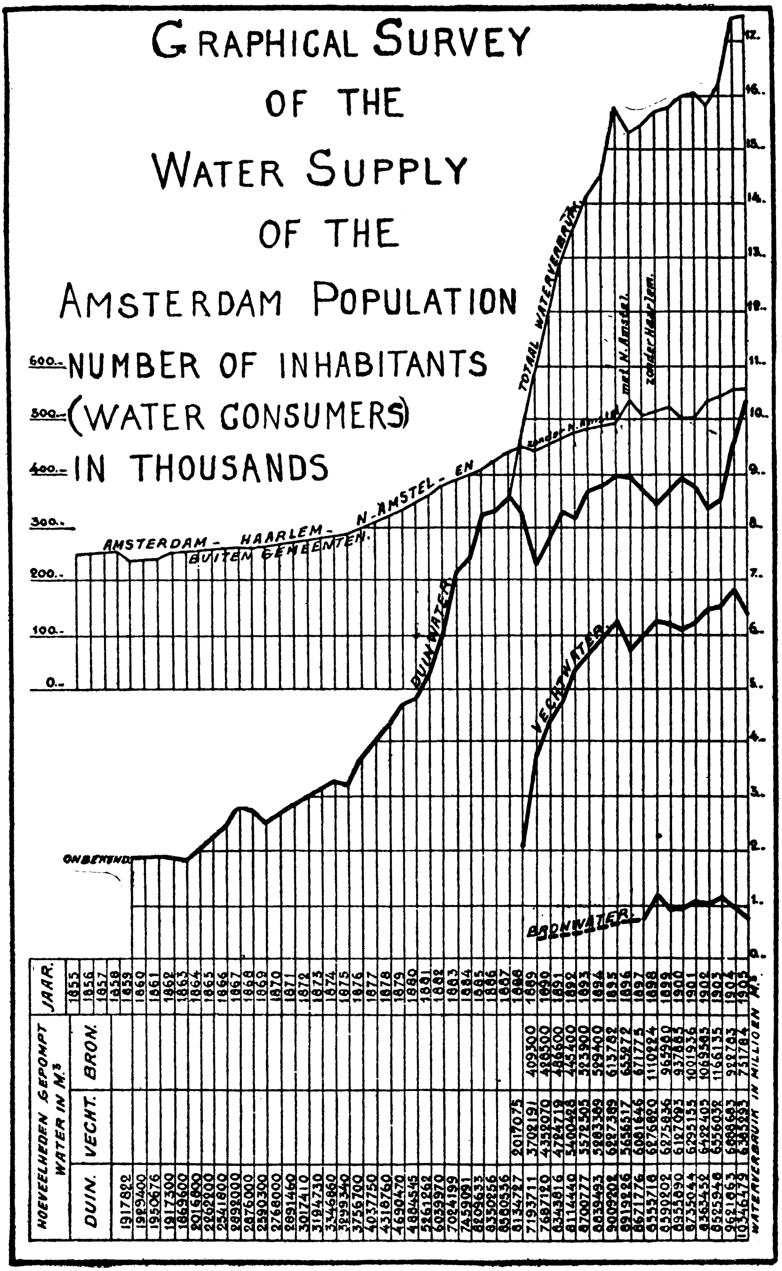
The supply of the Hill water was in a great part of the town wholly insufficient, and the agitation for municipal exploitation increased, till, after a long struggle, the town of Amsterdam took over the works of the Hill Water Company on May 1, 1896. In the meantime, by the increasing of its borders, the town came into possession of the Heathwater supply with a smaller capacity, which, since 1888, supplied the suburb Nieuwer-Amstel with heath water from the heath in the neighborhood of Hilversum.

The Heathwater supply, which provides a quarter of about 60,000 inhabitants by means of a water-tower with a reservoir of 500 cubic meter capacity, standing near the border of the town, receives the heathwater by a twelve-inch cast-iron pipe of twenty-seven kilometers length.

This water is pumped to the town from the pumping station by fifteen well pipes, from thirty-six to forty meters deep. It has no filtration. Since May 1, 1896, the town of Amsterdam has exploited accordingly three municipal water supplies, viz.:

1. The Hill Water supply, for domestic use.
2. The Heath water supply, for domestic use.
3. The Vecht water supply, for industrial and public purposes.

May 1, 1898, the supply from the dunes in behalf of the town of Haarlem was no longer continued, because this town had built waterworks for its own use. To improve the supply of Hill water in Amsterdam, after the community had come into possession of these works, great works of alteration and extension were immediately executed. In the dunes near Vogelenzang new canals were digged and the existing ones deepened. so that at the present time the Hill water is obtained from about twenty-five kilometers of open canals. Instead of the old pumping station a new one,


GRAPHICAL SURVEY
OF THE
WATER SUPPLY
OF THE
AMSTERDAM POPULATION
NUMBER OF INHABITANTS
(WATER CONSUMERS)
IN THOUSANDS
AMSTERDAM - HAARLEM - N.AMSTEL - EN
BUITEN GEMEENTEN.
TOTAAL WATERVERBRUIK
DUINWATER
VECHTWATER
BRONWATER
ONBEKEND
JAAR.
HOEVEELHEDEN GEPOMPT WATER IN M.³
DUIN.
VECHT.
BRON.
WATERVERBRUIK IN MILLIOENEN M.³

with two vertical triple-expansion engines, water-cellars and new filters was built; and in Amsterdam a low level reservoir of 10,000 cubic meter effective capacity, with a new pumping station at the Haarlemmerweg, which pumps the water directly into the town, was constructed. A large ring-pipe line was laid.

Charges to Consumers.—On May 15, 1900, the low-level reservoir and the pumping station at the Haarlemmerweg came into operation, and on January 1, 1901, the new pumping station near Vogelenzang. Since the extension and improvement of the network of pipes, completed, for the greatest part, in June, 1902, the Hill water can be delivered in all parts of the town with a pressure of twenty-five meters. In the town the pressure of the Heath and Vecht water amounts to from thirty-five to forty meters. The Vecht water, for public service, watering, fire-quenching, etc., is delivered cost-free; for industrial purposes, however, it is charged for by meter, and is computed at 10 à 15 cents per M^3 according to a special tariff. For domestic purposes the price of the Hill and Vecht water is computed according to the number of rooms.

See the graphical survey preceding.

SURVEY OF THE WATER DELIVERY PER MONTH AND PER DAY (1905).

Month.	Total consumption in M^3.			Consumption in liters per day and per head of Hill, Vecht and Heathwater.			Average number of inhabitants.
	Hillwater.	Vechtwater.	Heathwater.	Max.	Aver.	Min.	
January	803,880	449,032	58,389	90	77	57	551,777
February	738,538	398,436	52,202	90	77	57	552,539
March	813,329	439,353	60,319	86	76½	57½	553,169
April	807,167	499,786	52,127	94	82	60	553,505
May	906,728	612,527	60,293	116	92	67½	553 559
June	941,329	626,716	63,389	118	98	71	553,509
July	993,573	686,109	70,523	121	102	76	553,623
August	943,636	655,993	67,872	114	97	71	553,987
September	899,246	569,443	65,723	103½	92	70	554,686
October	874,630	490,212	64,540	94	83	62	555,548
November	819,823	477,333	69,459	94	82	61	556,423
December	809,600	480,353	66,948	94	78	55½	557,248
Year figure 1905	10,346,479	6,385,293	751,784	121	86	55½	554,515

The number of inhabitants amounted on January 1st, 1905, 551,416.
The number of inhabitants amounted on December 31st, 1905, 557,614.

Experience with Water Meters.—In total, about 3,600 water meters are in use, nearly all in industrial establishments. As for exactness the disk meters, marked "Etoile," give the best satisfaction.

Relation of Water Supply to Public Health.—See Schedule I hereafter.

Profits.—See Schedule II hereafter.

Present Condition of the Works. Plans for Improvement.—The examination of the dunes in the last three or four years has shown that the water, suitable for drinking, is to be found there at a depth of more than 100 meters, the drawing of water takes place from those deeper layers of sand by means of 100 well-pipes of about forty meters depth.

In many respects the works will soon be at the limit of their capacity, especially for the maximum consumption in summer. When this condition is reached the extension will be executed either by enlarging the three existing water works, or by building of a wholly new water supply. These propositions have for many years been under discussion, but no decision has yet been reached.

MORTALITY.

The mortality caused by febris typhoidea at Amsterdam in the years 1854-1905 compared to the use of the Hill water supply.

Years.	Average population.	Mortality caused by Febris Typhoidea.	Number of contracts for water delivery.	On 1000 inhabitants.		Years.	Average population.	Mortality caused by Febris Typhoidea.	Number of contracts for water delivery.	On 1000 inhabitants.	
				Mortality to Typh.	Contracts.					Mortality to Typh.	Contracts.
1854	250,500	370	960	1.48	3.8	1881	332,121	109	22,168	0.33	66.8
1855	254,395	544	1,695	2.14	6.7	1882	344,124	84	23,232	0.24	67.5
1856	257,696	485	2,231	1.88	8.7	1883	355,763	74	24,093	0.21	67.7
1857	259,955	499	3,198	1.92	12.3	1884	363,993	67	24,412	0.18	67.1
1858	260,282	480	3,676	1.84	14.1	1885	369,492	42	24,936	0.11	67.5
1859	251,915	403	4,413	1.60	17.5	1886	375,505	55	25,211	0.15	67.1
1860	244,188	313	5,031	1.28	20.6	1887	384,351	54	26,196	0.14	68.2
1861	246,713	272	5,597	1.10	22.7	1888	394,720	58	27,221	0.15	69.0
1862	251,685	268	6,285	1.06	25.0	1889	403,742	49	27,899	0.12	69.1
1863	256,752	301	7,138	1.17	27.8	1890	412,800	82	28,481	0.20	69.0
1864	259,099	367	7,801	1.12	30.1	1891	422,226	49	29,146	0.12	69.0
1865	261,199	368	8,578	1.41	32.8	1892	432,403	64	29,658	0.15	68.6
1866	263,594	256	9,293	0.97	34.6	1893	442,274	69	30,368	0.16	68.7
1867	266,062	261	9,960	0.98	37.4	1894	448,418	32	30,950	0.07	69.0
1868	269,695	295	10 797	1.09	40.0	1895	453,186	40	31,644	0.09	69.8
1869	268,431	294	11,427	1.09	42.6	1896[2]	{479,791 / 494,224}	41	39,313	0.08	79 5
1870	267,575	220	12,271	0.82	45.9						
1871	271,782	251	12,959	0.92	47.7	1897	489,572	45	39,205	0.09	80.1
1872[1]	275,638	202	13,542	0.73	49.1	1898	497,572	53	35,719	0.11	71.8
1873	279,854	149	14,265	0.53	51.0	1899	506,281	57	36,726	0.12	72.5
1874	284,438	105	15,200	0.37	53.4	1900	515,727	64	37,634	0.12	72.8
1875	288,457	112	16,223	0.39	56.2	1901	525,660	40	38,619	0.08	73.5
1876	293,091	93	17,318	0.32	59,1	1902	534,767	43	39,885	0.08	74.6
1877	299,233	89	18,393	0.30	61.5	1903	542,674	46	40,631	0.08	74.9
1878	305,607	131	19,730	0.43	64.6	1904	548,974	46	41,610	0.08	75.8
1879	312,979	96	20,405	0.31	65.2	1905	554,514	64	42,400	0.12	76.5
1880	321,603	167	21,080	0.52	6..6						

[1]In this year the law on the contagious disease was applicated.

[2]The contracts of the water supplies are calculated on the population ot the December 31; the mortality upon an average of the population.

II.

FINANCES OF THE AMSTERDAM WATERWORKS.

	1897	1898	1899	1900	1901	1902	1903	1904	1905
Expenses.	Florins	Florins	Florins	Florins	Florins	Florins	Florins	Florins	Florins
Salaries	120.028,60	121.521,13	129.268,56	137.831,11	165.621,17	185.064,33	185.979,81	188.351,90	196.708,01
Costs of offices and administration	18.070,63	21.352,50	20.299,28	23.013,95	28.296,33	27,784,21	28.564,43	28.237,04	51.177,94
Maintenance of the pipe-lines, etc.	57.384,45	56.417,43	72.215,67	81.927,32	94.310,81	140.952,61	138.743,79	141.375,76	119.617,22
Maintenance of the buildings and prise-d'eau	18.952,37	13.356,64	12.839,42	27.686,23	35.756,59	54.200,78	45.158,11	58.896,38	65.391,21
Maintenance and driving engines	66.989,41	78.866,18	96.786,95	130.846,97	192.571,27	109.196,21	118.909,80	129.502,77	115.851,73
Remaining expenses	27.508,12	34.659,51	42.276,06	57.654,52	67,882,63	68.313,24	78.061,62	78.550,12	68.440,27
Total	308.933,59	326.173,40	373.685,96	458.960,11	584.438,81	585.511,40	595.417,57	624.913,98	617.186,40
Receipts.									
Water delivery	1.460.279,74	1.422.084,51	1.432.932,47	1.475.421,54	1.531.159,73	1.582.616,37	1.680.147,55	1.745.335,94	1.777.305,17
Hire of meters	26.390,01	27.172,75	27.414,67	28.234,35	29.088,75	30.363,04	33.366,92	34,208.69	34.379,41
Remaining receipts	2.747,70	12.425,84	5.551,53	7.915,10	10.074,34	16.184,43	23,293,10	26.323,45	29.356,95
Total	1.489.417,46	1.461.683,11	1.465.898,67	1.511.570,99	1.570.322,82	1.629.163,84	1.736.807,57	1.805.868,09	1.841.041,54
Net receipts	1.180.483,86	1.135.509,71	1.092.212,71	1.047.512,99	985.884,01	1.043.652,44	1.141.389,99	1.180.954,11	1.223.855,14
Of which there was used for									
Payment to the community	100.000,00	100.000,00	100.000,00	100.000,00	100.000,00	100.000,00	100.000,00	150.000,00	150.000,00
Interest	326.090.83	320.890,42	315.565,00	329.407,30	359.612,28	382.425,38	383.222,24	398.079,49	397.056,30
Amortization	198.000,00	203.000,00	208.000,00	213.000,00	233.320,99	252.155,67	275,815,28	280.815,28	285.815,28
Reserve	556,393.03	511.619,29	468.647,71	410.203,58	292.950,74	309.071,38	378.352,47	352.059.34	390.983,56

The Chemical Analyses were over 1905, upon an average (in milligram per liter).

Averages over 1905.	Hillwater.[3]	Heathwater.	Vechtwater [3]
Klewr in (m. G. Caramel) per Liter...	4	colourless	8.8
Vaste stoffen, gedroogd by 180° C...	351.7	88.9	443.2
Gloeiverlies	19.6	6.2	40.5
Yzeroxÿde (Fe_2O_3)	0	0	0
Calciumoxÿde (CaO)	134.5	27.1	101.4
Magnesiumoxÿde (MgO)	9.8	2.4	19.7
Zwavelzuur (SO_3)	26.6	3.3	28.4
Chloor (Cl)	32.3	13.5	134.8
Kiezelzuur (SiO_2)	16.6	9.1	2.3
Ammoniak (H_3N)	0	0	0.012
Albuminoid ammoniak	0.072	0	0.117
Salpeterigzuur (N_2O_3)	0	0	0
Salpeterzuur (N_2O_5)	2.20	0.52	3.69
Zuwistofin cub c. M. per liter (O_2)...	5.85	4.09	5.51
Koolzuur (vry enhalfgebonden (CO_2)	105.	28	70
Kaliumpermanganaat ter oxÿdatie der-org. stoffen ($KMaO_4$)	5.2	0.32	11.4
Totale hardheid in Duitsche graden $\left(\frac{Ca\,O + 1,4\,Mg\,O}{10}\right)$	14.82	3.04	12.90

BERLIN, GERMANY

By Professor Dr. Conrad Bornhak, University of Berlin.

The present water works of Berlin consist of two establishments, Tegel-Charlottenburg and Müggelsee-Lichtenberg. These supply the entire city of 2,500,000 inhabitants up to a maximum demand of 100 liters per capita. This quantity of water represents a supply of three cubic meters per second, and is divided between the two works, the Tegel station supplying one-third and the Müggelsee station two-thirds. The former works contain two divisions and the latter three, each of which may be operated separately. Tegel and Müggelsee are the supply stations where the water is stored and from which it is delivered to the intermediate water stations of Charlottenburg and Müggelsee. The reservoirs for purifying the water are found in the former places and in them the large quantities pumped in night and day are held. It is there stored up during the hours when the demand is lowest and drawn off during the hours of greatest use.

The water of Berlin in recent years has been supplied entirely from ground wells. Formerly the Tegel Lake was used as a source of supply. In the 70's of the last century an appropriation of land in the vicinity of Tegel was made from which well water was drawn from twenty-three wells but it was soon found that this water was polluted. It contained a large

[3]Filtered water.

amount of iron and certain algæ also made its use unadvisable. All the city officers made strenuous efforts to eliminate these bad qualities, but the question of supplying good well water to Berlin remained unsolved and at that time was given up as unsolvable. Later, however, renewed investigations with drilled wells in the vicinity of Müggelsee and Tegel were followed with such favorable reports that the technical possibility of supplying Berlin with good well water was put beyond doubt.

The explanation of this discovery of good water in the immediate vicinity of the wells formerly condemned is found in the fact that the earlier wells averaged only sixteen meters in depth. The deepest one was not more than twenty-five meters, while the new driven wells were sunk to at least fifty meters. With these greater depths the former presence of algæ, which had rendered the well water unfit for use, was eliminated, and the iron also disappeared. With the disappearance of iron practically all the carbonic acid gas was also eliminated. To this fact was due the elimination of the algæ which needed this substance for their nourishment. It was now felt that well water should be supplied to Berlin to the exclusion of the use of filtered surface water the well water possessing a distinct advantage over the other in its freedom from germs.

The very favorable lay of the land which acted as a natural filter for the rain water sinking through it, brought it about that the well water was entirely free from bacteria. A further advantage in favor of well water is its uniform temperature of 10° Celsius in contrast to the water from the rivers which was always too warm in summer and too cold in winter. Although the advantages and practicability of supplying the well water to Berlin were well known, the general public was not aroused to bringing about any change in the passable good service formerly rendered from the Tegel plant.

Not until other circumstances forced a change did the city transform its water supply system. The rapid growth of population of late years had forced the northern suburbs of Berlin to establish large drainage areas whose outlet was the Tegel Lake. As this was the natural means of drainage for the regions involved, the officers of the city believing that it involved no danger to the health of the community, did not feel justified in refusing the suburbs the privilege of sending their sewage into the lake, especially as these communities were not in a financial position to provide other means of disposal such as filter fields. The dangers of pollution of the Tegel Lake could have been removed by the transference of the sewage outlet to a point farther down the River Spree near Fürstenbrunn. However, this would have involved considerable expense. This remedy was not adopted, however, because the community of Reinickendorf was about to install a similar drainage system into the lake which could not be disposed of in the same way.

The royal government now placed upon the City of Berlin the duty of transferring its water supply to the use of well water exclusively as it was evident that the Tegel Lake could not permanently be kept clean as a source of supply. The beginning in exploration for new well locations was made

in 1899, five deep wells and eighty-one exploring tubes were sunk in the Tegel forest. These explorations showed that the supply of ground water was sufficient to furnish the quantity formerly supplied from the lake. This could be done without lowering the level of the water to such a degree that it would interfere with forest projects or agricultural operations. This conclusion having been reached, both branches of the Tegel supply were transformed in succession, the first division for furnishing water from the new wells coming into use in 1901 and the secod section in 1903.

Meanwhile the transformation of the Müggelsee works was under way. The situation at Müggelsee was not so unfavorable as yet as at Tegel, although similar bad conditions had made their appearance and were to be feared even more in the future. The factories in the neighborhood were growing in a remarkable degree and emptied their sewage into the Spree. In addition, the floods of the spring and fall in the Spree forests carried into the water a large amount of humus which gave it a yellow color and made it unfit for use. The explorations in this neighborhood had produced even better results than at Tegel, so the city authorities decided to rebuild entirely the Müggelsee works. The modification will be completed by the end of the present year. The following table shows the development of the use of water in the City of Berlin from the beginning of the water-works system:

Year.	Districts supplied with water.	Total water delivered in the city in cubic meters.	Per capita use of water per day (liters).	Total quantity of water delivered on one day in the year.			
				Greatest.		Least.	
				Cubic meters.	Date.	Cubic meters.	Date.
1857 ...	669	2,462,836	224.00	.....	.....	.....	.....
1862 ...	2,359	3,919,823	101.00	18,246	7.6	5,830	1.1
1867 ...	5,500	9,213,951	104.00	34,353	31.8	16,068	22.4
1872 ...	7,524	13,953,070	79.00	54,575	27.7	24,107	7.1
1876 ...	9,649	17,537,030	90.00	62,468	19.8	33,677	1.1
1877 ...	12,365	20,545,845	90.00	76,210	24.8	37,210	Feb.
1882 ...	16,876	22,434,532	63.70	82,010	15.7	46,557	1.2
1887 ...	19,193	30,877,360	64.87	119,215	30.7	61,606	25.12
1892 ...	22,638	40,035,922	67.13	163,976	25.8	75,645	26.12
1897 ...	24,662	49,882,328	77.87	202,385	30.6	94,510	2.1
1902 ...	26,525	55,142,646	79.13	218,220	4.6	104,011	25.12
1904 ...	27,806	60,861,335	84.17	251,174	16.7	109,793	26.12

The decrease in the average use of water from 224 liters to about sixty-three liters in 1882 per head per day is explained in the fact that formerly the water was supplied without being metered, after a payment of a set yearly tax; while later, with the gradual introduction of water meters, it was sold exclusively by quantity. In 1878 the water meter was permanently installed throughout the city, and the quantity used diminished with great rapidity. The table shows further that the average use is growing both in the periods of least and of greatest demand. At present water is sold at fifteen pfennige a cubic meter. Aside from this a fixed water tax of four marks is levied quarterly on every property.

Even while the project for the enlargement of the Müggelsee plant was being made the daily use could be reckoned at 100 liters, but at the present time the highest use per inhabitant per day exceeds 130 liters. When it is taken into consideration that the use of water in each city necessarily increases with the growth of the city, and that in Berlin the higher portions of the city are more and more being taken up as residence districts where the establishment of private wells is impossible, it is seen that the consumption will grow to at least 160 liters. A later estimate gives the need of Berlin when it has 2,700,000 inhabitants as 430,000 cubic meters per day. Moreover, the suburbs of Weissensee Niederschöneweide, Treptow and Stralau, with an area of about 1,000 hectares, have been taken into the district supplied with water by the city. The future need of this district may reach 50,000 cubic meters per day, so that a safe supply in the times of greatest consumption will depend upon an ability to deliver 480,000 cubic meters per day. Inasmuch as at the present time the daily delivery of the present works is 260,000 cubic meters, it is evident that the creation of other establishments is a matter of pressing necessity. Beginnings have already been made in planning these extensions.

COPENHAGEN, DENMARK

By Dr. William Scharling, Copenhagen.

The water-works of Copenhagen are municipal. They were built in 1859 and have been several times enlarged because of the growth of the city (1855, 155,000; 1906, 426,000 inhabitants). A new system, yielding daily 17,000 cubic meters, is expected to be ready for work at end of 1908; at present the average daily consumption is 102.33 liters per head.

The water-work is high pressure work, ground water, with sand filtration. The water comes from bored wells, is without germs and of extremely good quality; the establishment of these works has been of great hygienic importance to the inhabitants of the city. Other hygienic amelioration contributing, the mortality of Copenhagen has been steadily decreasing: 1865-74 an average 261 per 10,000; 1875-84, 246; 1885-89, 221; 1890-94, 214; 1895-1900, 177.

The charges to consumers are partly based upon the area of building, partly by the tap and partly by meter. Meters are compulsory only for industrial use and for water closets, but appear to be very suitable. The charges have in 1905-06 given the municipality an income of 614,000 kroner (1 kroner equals 27 cents); the expenses have been 490,000 kroner. The works give thus a good profit on the amount invested. The capital bound up in the works is 9,480,000 kroner; they give thus an interest of more than 5 per cent.

The plans of extending the work will be ready in 1908, and are to furnish a high reservoir to contain 20,000 cubic meters.

STOCKHOLM, SWEDEN

By O. NORDENSTRAHL, Stockholm.

December 6, 1855, it was decided to supply Stockholm with water from the lake Malaren after the plans made by Captain F. W. Leijonancker, and for that purpose an appropriation of kronor 1,150,000 was provided. In the year 1858 the work was begun, and July 1, 1861, the plant was put into operation.

This first plant consisted of two vertical-balance steam-pumps with four boilers mounted in one engine-house, and one boiler-house, one administration building, three basins for sand filtration with a combined surface of 1,574 cubic meters, one pump-well with necessary pipes; the pipe system in the city and one high-pressure reservoir of 5,100 cubic meters capacity. The capacity was 5,000 cubic meters per diem for each pump.

As the population, and with it the water consumption, has increased, the plant has been added to, until it in 1898 consisted of four pumps with an output for each of 10,000 cubic meters, twenty-two open basins for filtration with a total surface of 17,710 cubic meters, four water reservoirs of 20,400 cubic meters capacity, and a line of pipes of 181,000 meters. The inside diameter of the pipes varied from 51 to 610 millimeters.

As the demand on the water-works still continued to grow, and for various reasons was found inadvisable to add new parts to the old plant, it was finally decided to build a new station at Norsborg, some twenty kilometers southeast of Stockholm, between the lakes Malaren and Bom. This latter lake is giving an exceptionally clear and good water, as it is surrounded by woods, and on one side is skirted by a gravel ridge from which several springs send their waters to the lake. The city bought the surrounding land in order to be sole possessor of the lake. In the years 1901-04 the new plant was erected here, comprising one tunnel to lead the water from the lake to the filters, three roofed sand filters of 1,550 cubic meters surface each, one pumping-well, engine and boiler-house, two horizontal pumps, driven by two double-cylindric engines, four boilers, electric power and lighting plant, administration building, seven houses for the functionaries, etc. In addition to this, there is a ground-water plant to take up the water from the stone ridge. This comprises two wells, thirty-three and eighteen meters deep, two electric pumps, and one iron filter to take the iron out of the ground water. This part of the plant yields 3,000 cubic meters, and the combined plant 33,000 cubic meters per diem. A cast-iron pipe, 102 centimeters in diameter, carries the water to a high reservoir of 18,000 cubic meters outside the city, and from this reservoir a pipe of 122 centimeters diameter conducts the water to the pipe system in the city. The supply of water available from these lakes is unlimited.

As to charges to consumers, each house owner pays for general use in the household and for each room in the house, two kronor per annum.

For other purposes the water is sold at 20-16 öre per cubic meter. The city, for the water used for its own purposes, credits the water-works with

12 öre per cubic meter. The average daily per capita consumption has been 100 liters with a maximum of 150 and a minimum of 53.4 liter.

Of water meters there were, in 1906, 2,100 in use, principally turbine meters of Siemen's & Halske's and Meinecke's construction. Another meter of French make has also been used. The experience has proved this to be the best way of distributing the water, the justest to the consumers and the only possible to prevent waste.

The public health has been directly proportional to the increasing water consumption and the improvement control of the source of supply.

The total consumption for 1906 reached 11,644,716 cubic meters. The pipe system was 238,330 meters in length, with a capacity of 26,132 cubic meters. The total value of the water-works is 16,042,759.83 kronor.

The income of the works in 1906 was 1,231,144 kronor, and the expenditure 888,872 kronor. Thus the profits for the same year netted 348,251 kronor toward payment of the debts.

The plans for improvement contemplate additions to the works at the lake Bom until they shall yield 100,000 cubic meters per diem.

UPSALA, SWEDEN

By G. LAURELL, Upsala.

History of the Establishment of the Water Supply.—The Upsula water-works were started in 1875, drawing their supply of water from the gravel ridge, at the foot of which Upsula is situated. The supply is abundant and widely known for its clear and healthful qualities. As the demand on the water supply has grown, new wells have been opened, the last addition having been made in 1905. The supply will probably be sufficient for any increase in demand that may be expected.

No charge is made to private consumers for water to fill household demands. An exception is, however, made for houses heated by water, for which a small annual sum is charged. Factories, buildings in erection and stables have also to pay annually for water consumed, the buildings in erection paying for water in proportion to the number of bricks in the building, and the stables paying in proportion to number of horses. The factories pay for the quantity of water as measured by meters.

The average daily per capita consumption for the years 1904 and 1905 has been 107 liter, and for the year 1906, 105 liter. So far water meters have only been used in the case of factories as mentioned above. At present only about 100 are in use.

The maximum capacity of the pumps is 120 liter per second. The length of pipe had at the end of 1906 was 33,700 meters, and the total value of the whole plant was 608,300 kronor. As the water is mostly delivered free of charge, the income does not cover the expenditure, the balance generally amounting to about 4,000 kronor annually.

The present supply is adequate to the immediate needs and there are consequently no plans for enlargement.

MADRID, SPAIN

By CHESTER LLOYD JONES, PH.D., University of Pennsylvania.

The water supply of Madrid is furnished partly by the national government and partly by the city. The water is brought to the city limits from the River Lozoya, a snow-fed stream in the Guadarrama Mountains. This source of supply was brought to the city in 1858 by the central government and gave to Madrid for the first time an adequate supply of water. Up to that date shallow-dug wells were the sole resource. Since then the rapidly increasing population and increased use of water by public fountains and in irrigation have necessitated large additions to the original plant. The population supplied has grown in the period from 1855-1904 from 200,000 inhabitants to 560,000, and the superficial area supplied has increased from 700 hectares to 2,200. The water consumption per day has increased during the same period from 2,000 to 140,000 cubic meters. In proportion to the population this means a use of water at the present time twenty-five times greater than that in 1855. The price per cubic meter has fallen from one-eighth to one-forty-sixth that charged in 1855.

The supply is more than adequate for the needs of all but the higher portions of the city. Indeed, a comparison of the amount of water used in Madrid with that consumed in other important cities shows that only in New York and Rome is a larger amount consumed per inhabitant per day.[4] The daily consumption in Madrid amounts to 250 liters per inhabitant; in Rome, 1,000; in New York, 300; in Paris, 216; in London, 159; and in Berlin, 80.

From the first the method of adjusting water rates has been open to many abuses which have only recently been remedied. The City of Madrid is granted a certain amount free for public uses within her borders, and for all that used above that amount granted free the charge is at the rate of two and one-half pesetas for a supply of one hectoliter per day for a year. The charges within the city have been settled by the municipal government. Certain charitable institutions receive the water gratis and it is also supplied to public fountains without charge, but no individuals at the present time can legally receive such concessions. The water granted for public use is largely wasted as the city uses over 40,000 cubic meters per day. This laxness of administration is due to the fact that the charges for extra water for public use beyond the free grant are not enforced. It is said that in 1906 the city used over 40,000 cubic meters, though only a little over 6,000 were granted freely. For this additional amount no charge was levied against the city. The charge to individuals has, until recently, been based upon the number of faucets in use no matter what the quantity used. Meters are now being introduced, the charge varying from .30 pesetas down to .05 pesetas per cubic meter. This is a service equaled in cheapness by but few other large European cities.

The quality of the water is said to be excellent. The sources from

[4]Memoria sobre el Estado de los diferentes servicios. (Canal de Isabella II, p. 158. Madrid, 1907.)

which it is taken, far up in the mountains, are free from all bacteria and harmful chemical elements. The canal through which it is brought to Madrid, however, is uncovered, and an objectional amount of vegetable and animal matter finds its way into the water, necessitating sand filtration. Statistics showing the effect of the improved water service upon public health have not been collected, but officials claim a marked improvement in all hygienic conditions. The rapid increase in the population of the city, as noted above, it is claimed is due in large part to the excellent water supply.

The sources from which Madrid draws her supply promise to be ample for all growth in population for many years. The amount of water which can be delivered through the present canal can be increased to 300,000 cubic meters per day, equal to 600 liters per day per inhabitant for a population of 500,000, or 300 liters per day for a city of one million inhabitants—a figure at which Madrid will not arrive for several generations. Nevertheless there are plans to increase the possible water supply, while at the same time providing means for irrigation to the surounding country. The agricultural rejuvenation of Spain by irrigation, so much talked of, promises to bring in its wake a supply of water far beyond what the population of the metropolitan district will demand for ordinary municipal needs. A new set of canals from the Guadalix River is already in process of construction and will furnish an additional resource of six million cubic meters. Plans are also being made for a larger water supply to the high parts of the city and to the low-lying suburbs.